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THE UNSOUNDNESS OF CERTAIN TYPES OF ROCKS

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Geologists, working in coöperation with highway engineers, have been of great assistance to them, and of great economic service to the public in searching out sources of material, in classifying and identifying rock formations, and in passing judgment upon the suitability of different rocks for use in highway projects. More recently geologists have rendered great assistance in the study of slides in earth embankments in both the cut and fill sections. All of these and innumerable other associations have developed the mutual respect and spirit of coöperation now existing between geologists and highway engineers. This seems particularly fitting since the rocks and soils studied by the geologist are so closely associated with the works of the highway engineer which are constructed of these materials, and finished in contact with members of the same materials.

As time goes on and the store of knowledge regarding rocks and highway engineering structures increases, additional opportunities for coöperative endeavor are offered. For example, there is the study of the durability of one of the products of the highway engineer, that artificial rock, modern concrete. The phase of this problem of durability of interest to the geologist is that in which the presence of certain types of rocks directly affects the integrity of the mass of concrete by their particular behavior when exposed to wide ranges of temperature and variations of moisture content.

Various rocks, when exposed to weathering, undergo apparent alterations of form. Others appear to be unaffected, at least for the short period of time within the range of observations of a single generation of engineers. Those that fail to resist the attack of the elements are referred to as unsound, and the others as sound rocks. At the present time there is but limited knowledge of the behavior of these unsound rocks when encased in concrete. It is known that a number of them decompose or disintegrate and leave a hole when near the surface of the concrete. Those of another group have apparently a great volume change when subjected to wide ranges of temperature. Still another group has apparently a similarly great volume change which is due both to temperature changes and variations of moisture content. Individual pieces of either of these latter two groups of rocks when near the surface force out large spalls of concrete. Therefore, like the disintegration of the first type, the effects of the volume change rocks are, as yet, surface manifestations. The affect on the mass of concrete when sufficiently thick around each piece of unsound rock to prevent spalling is unknown.

Among highway engineers there has been recently considerable speculation as to these unseen effects of all of these unsound rocks upon the durability of concrete. The effect on the structural strength of the concrete may be determined by direct tests occupying but a short period of time, but as yet, no direct tests of durability other than observations over a long period of time are available. It is known, however, that some of the unsound rocks appear to be sound, at least for long periods of time, when wholly encased in concrete. It may be that geologists can offer some assistance in the solution of the problem through their knowledge of the disintegration and decomposition of rocks exposed to weathering conditions but not in direct contact with the air.

Unsoundness in rocks exposed to weathering becomes apparent, for different types of unsound rocks, after different periods of time. Some short and some long, say several years. It frequently becomes necessary for the testing engineer to make disposition on a certain type of rock proposed for use in concrete, but a short time before the rock is to be used. For this reason the highway engineer and others make use of various accelerated weathering tests. The two most common of these tests are the Sodium Sulphate test and the Freezing and Thawing test. Neither of these tests is wholly standardized, but as used by each testing engineer, either test permits a fairly definite classification of the rocks of his locality. In use, the test may be repeated a certain specified number of times or continued until the unsound rocks have been reduced to the same degree of disintegration attained when the effects of natural weathering become apparent. In either case the specifications permit the use of rocks passing a specified number of repetitions of the test. Space does not permit a description of these tests here at this time. It is sufficient to say that they were developed merely for the purpose of obtaining in a short period of time the effect upon the rock that may be obtained when the rock is exposed to a long period of natural weathering. Insofar as has been learned, there is no chemical action upon the rock in either test.

Classification of Unsound Rock

Although the unsound rocks have attracted considerable attention on account of the conspicuousness of their behavior when exposed near the surface of the concrete, they compose but a small percentage of the total amount of rock used in concrete. The specifications for the construction of concrete on the Primary Road System of Iowa limit the amount of unsound material to a maximum of three percent except in the case of chert. At the present time there is no specified limit for the amount of this material.

For some time the Research Division of the Iowa State Highway Commission has been studying the various types of unsound rocks for the purpose of establishing the maximum limit for the total amount of unsound rock which may be permitted in either gravel or crushed limestone for use as coarse aggregate in concrete. In this study, observations are being made of existing structures for which there is available a definite knowledge of the total amount of unsound material. As a result of this study and the accumulated experiences of the past ten years in the use of gravels and limestones available in Iowa, a classification of unsound rocks has been prepared. This classification of unsound rocks, without reference to their scientific nomenclature, appears in the table shown below.

Table I — Classification of Unsound Rocks

A. Sedimentary Rocks	B. Igneous Rocks
1. Iron Oxides	1. Disintegrating Granites
2. Iron Stones	
3. Shales	
4. Shaley Limestones	
5. Shales Impregnated with Iron Oxide	
6. Shales Coated with Iron Stone	
7. Cherts	
8. Miscellaneous Soft, Earthy Rocks	

Distribution

As may be seen from the table, these rocks have a wide distribution throughout the state. Some one, or all of them, may be found in each of the commercial sand, gravel or limestone deposits producing material for use in the construction of highway projects. The commercial sand and gravel deposits in the Wisconsin Drift area are particularly infested with some one or all of these types, excepting the cherts and shaley limestones. For this reason, the Wisconsin Drift, although the most abundant source of sand and gravel in the state, offers many difficulties and hazards to the commercial production of concrete aggregates.

In the limestone deposits, strata of shaley limestone are frequently so numerous and so high a percentage of the quantity of stone available as to prevent the operation of the deposit for the production of material for use in concrete. In some of the workable limestone deposits the quantity of chert may be from one to five percent of the total quantity of material produced. In some cases, quantities of chert in excess of about three percent have produced an unsatisfactory appearance in the surface of the concrete pavement.

Classification of Failures

The two types of failure of unsound rock in concrete are so definite and so distinctly different that they may be placed in two classifications. In the Type I failures the rock fails by disintegration without appreciably affecting the surrounding mortar or the concrete. In the Type II failures the rock, through its disruptive force, affects a much greater volume than the volume of the unsound particle. A detailed description of each of these types of failures follows.

Rocks Failing by Disintegration

Type I Failures

A number of unsound rocks apparently fail by disintegration which is accompanied by but little volume change of the rock, or at least, if there is a tendency for volume change, insufficient force is developed to disrupt more than a very thin coating of concrete. The effect of unsoundness for this type of rock consists merely of a hole or pit in the surface of the concrete. Within a few years after the evidence of unsoundness is apparent the majority of the rock originally in the pit is completely disintegrated by the action of frost and alternations of wetting and drying. The action of traffic removes the products of disintegration and there remains in the pavement merely a cast or mold of the original rock.

The rocks in this class are Iron Oxides, Iron Stones, some of the Shales, and Miscellaneous Soft, Earthy Rocks. These rocks are found in the gravel produced from glacial deposits. The Iron Oxides occur as soft, earthy or ocherous pebbles. The Iron Stones are somewhat harder, varying in hardness from pebbles that can barely be crushed in the fingers to those that are difficult to break with a hammer. The Iron Stones are distinguished from the Iron Oxides in that their composition seems to consist of Iron Oxide and clay, rather than some form of Iron Oxide alone. The shales which merely disintegrate are so soft as to sometimes be classified as clay. The miscellaneous soft, earthy rocks are soft limestones, soft sandstones and other unclassified soft stones which may be readily broken in the fingers. There is another class of soft stone which may be broken with the fingers but passes the soundness tests, both in the laboratory and when exposed to natural weathering conditions. This material is not to be confused with the unsound soft material, in the class just described.

Rocks Failing by Disintegration Accompanied by Appreciable Volume Changes

Type II Future

In this class are placed all of those rocks which cause failure in the concrete by disruptive action. These rocks for the most part disintegrate without apparent change in the composition of the rock. Each individual particle resulting from the disintegration retains all of the characteristics of the original rock until it is reduced to such a size as to be no longer examined visually.

A typical failure of a fragment of this rock forces out of the structure a rough cone shaped piece of concrete in which the disintegrating rock is at the apex of the cone and the exposed surface of the concrete forms the base. At the corners of concrete structures quite large spalls are frequently broken off by the disruptive action of the disintegrating rock. In the plane surface of the concrete pavement the broken out cones of concrete remain in position for an indefinite time. Some of them break out under the action of traffic, and others are difficult to remove even with the aid of tools. In either case the strength of the concrete structure and its appearance have been seriously affected. The action of the disintegrating rock thus forces out, when near the surface, or even at some distance from the surface, in the cone of broken out concrete a volume of concrete several times in excess of the volume of the rock causing the failure. Hence, small quantities of this rock do proportionally great damage.

The rocks falling in the class having sufficient disruptive force accompanying their volume change during disintegration to cause coning or spalling of concrete are Shales, Shaley Limestones, Shale impregnated with Iron Oxide, Shale coated with Iron Stone, and Cherts. The shales, except for the shaley limestones, occur exclusively in the glacial deposits. The shaley limestone occur in limestone deposits and the cherts occur only in these deposits, in Iowa. The shales vary in hardness from firm clay to hard slate. At some point before the hard slate classification is reached the shales seem to lose their troublesome characteristics insofar as concrete is concerned. The hard slatey shale is rare in Iowa, and where it has been used in concrete has not resulted in the typical failures observed for the other classes of shale. Another class of shale is that found in the limestone deposits. In these deposits it is usually so soft and friable that it may be screened out of the crushed product during dry weather. In wet weather it causes clogging of the screens and the resulting crushed product is unfit for use in concrete. The shaley limestone varies in hardness from hard clay to that of fairly good limestone. Its presence is some times a little difficult to detect. In most cases, however, it has a different color when wet than when dry. Examinations of the crushed product in a wet or moist condition will usually permit ready classification of this material, particularly of those phases which are unsound. The shale impregnated with iron oxide seems to be merely a shale of medium hardness impregnated with iron oxide to such an extent that the specific gravity of the shale is sometimes doubled. Its behavior is identical with that of unimpregnated shale. The shale coated with iron stone or iron oxide is ordinarily quite soft shale completely coated with a hard iron stone or iron oxide coating. Many of these pebbles are extremely difficult to break with a hammer but show disintegration when exposed to the freezing and thawing test. This disintegration is apparently accompanied by considerable volume change and the spalling and coning of concrete resulting from this disintegration is the same as for the other shales except that they may be influenced by the shape of the pebbles. A great many pieces of this class of unsound rock occur as rectangular or slab shaped pieces.

The only unsound member of the igneous rocks occurring in Iowa is found in the disintegrating granite pebbles appearing occasionally in material from glacial deposits. Usually the conditioning process incidental to the production of gravel at these deposits reduces the disintegrating granite to such an extent thta its remains are found only in the sand produced at these plants. In a few instances there has been enough of this disintegrating material produced as to appreciably reduce the normal strength of the sand. This however is rare, and of little consequence insofar as the general production of material from glacial deposits is concerned.

In the presence of cement and water a few of the unsound stones indicate that they have probably been attacked by some chemical action of this medium. This is particularly true of the soft iron oxides and the iron oxide coatings on some of the other soft, unsound stones. Otherwise, no apparent result of chemical activity has been noticed.

Within the next few months the Research Division of the Iowa

State Highway Commission expects to have under way a rather extensive series of tests for the purpose of determining the volume changes of the different types of rock and of concrete. One objective of this research is to determine the difference in volume change between the unsound rocks and sound rocks and the mortar matrix in which they are encased in concrete. Also it is expected to determine the maximum difference in volume change which may be permitted in an unsound stone before it may cause, when disintegrating, a disruptive action upon the concrete.

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